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Sustainable Collusion on Separate Markets

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Abstract

When firms can supply several separate markets, collusion can take two forms. Either firms establish production quotas on all the markets, or they share markets. This paper compares production quotas and market sharing agreements in a Cournot duopoly where firms incur a fixed cost for serving each market. We show that there exists a threshold value of the fixed cost such that collusion is easier to sustain with production quotas below the threshold and with market sharing agreements above the threshold. These results are obtained both under Nash reversion strategies and the globally optimal punishment strategies introduced by Abreu (1986).

KEYWORDS: Implicit Collusion, Market Sharing Agreements, Production Quotas, Optimal Punishment.

JEL CLASSIFICATION NUMBERS: L11, L12

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1 Introduction

When firms can supply several separate markets, collusion can take two distinct forms. Either firms are present and establish production quotas on all the markets, or firms are active on separate markets and commit not to enter each other's market. The first form of collusion (production quotas) has been extensively studied in the literature; the second form of collusion (market sharing agreements) has not yet been fully analyzed. Our objective in this paper is to compare these two forms of collusion, and to study under which conditions maximal collusion is easier to sustain with production quotas or market sharing agreements.

The empirical and theoretical literature on collusion has mainly focused on price-fixing cartels with production quotas. Market sharing agreements have recently gained attention from antitrust authorities as the globalization of markets and the deregulation of industries which used to be regulated on a territorial basis (airlines, local telecommunication services and utilities) have increased the scope for explicit or implicit market sharing agreements. For example, in its 1999 merger guidelines, the Irish Competition Authority states that:

> "As an alternative to a price-fixing cartel, firms [...] may divide up the country between them and agree not to sell in each other's designated area. [...] At its simplest, a market-sharing cartel may be no more than an agreement among firms not to approach each other's customers or not to sell to those in a particular area. This may involve secretly allocating specific territories to one another or agreeing on lists of which customers are to be allocated to which firm." (Irish Competition Authority, 1999).

The European Commission has been particularly aware of the potential risk of market sharing, as firms which used to enjoy monopoly power in some territories seem reluctant to compete on the global European market. In a landmark case against Solvay and ICI, in 1990, the European Commission has established that the two companies had operated a market sharing agreement for many years by confining their soda-ash activities to their traditional home markets, namely continental western Europe for Solvay and the United Kingdom for ICI. It was also found that over many years, all the soda-ash producers in Europe accepted and acted upon the 'home market' principle, under which each producer limited its sales to the country or countries in which it had established production facilities.[1] More recently, the first decision taken by the new Competition Commissioner, Neelie Kroes on December 9, 2004, specifically struck down three large chemical companies, BASF, Akzo Nobel and UCB for operating a market sharing agreement with American companies in animal vitamins. The Commission noted that

> "Cartel operators met in secret from 1992 to 1994 to increase worldwide prices and allocate global markets. The North American producers agreed to withdraw from Europe in exchange for the European producers withdrawing from North America."[2]

In the United States, the Telecommunications Act of 1996 was specifically designed to encourage regional operators to enter each other's market. Eight years later, it appears that both industries are still dominated by a handful of dominant companies, each with highly clustered regional monopolies.[3]

In order to compare production quotas and market sharing agreements, we consider two identical firms who can be active on two separate markets, and compete by setting quantities.[4] We suppose that firms incur a fixed

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[1] See *Official Journal* L 152 , 15/06/1991, pp. 1-15.

[2] For an account of this decision, see http://tinyurl.com/9a3xh (last visited in December 2004).

[3] The major providers of cable and local phone service seem to have chosen to merge rather than compete. For example, thanks to a series of mergers, the Regional Bell Operating Companies have shrunk to seven companies in 1996 into just four today. The last of these mergers (between SBC and Ameritech) was subjected to a list of conditions requiring the merged company to open its in-region local markets to competition and to enter local markets outside its 13-state region. The conditions that the Federal Communications Commission imposed made clear how dissatisfied the agency was with the progress of local competition under the Telecommunications Act of 1996 (Wilmer, Cutler & Pickering, 1999).

[4] As we discuss below, the case of price competition yields trivial results, as the incentives to deviate from the cooperative agreement are identical under production quotas and market sharing agreements.

cost to serve every market, so that supplying both markets involves paying twice the fixed cost.[5] The firms can either collude by producing half the monopoly quantity on both markets (production quotas), or by producing the full monopoly quantity on a single market (market sharing agreements).

We compare the two forms of collusion by computing the minimal value of the discount factor for which collusion can be sustained in a subgame perfect equilibrium of repeated interaction. We consider both the classical model of Nash reversion (Friedman, 1971) where firms switch to the noncooperative Nash equilibrium of the Cournot game after a deviation, and the optimal punishment schemes (Abreu, 1986), where firms adopt an optimal "stick-and-carrot" punishment scheme after a deviation. While the details of the analysis differ in both models, the qualitative results remain similar.

First, we note that when fixed costs are very low, *collusion is easier to sustain with production quotas than with market sharing agreements*. The intuition underlying this result is easily grasped. For low values of the fixed cost, both forms of collusion give rise approximately to the same profit. Under general conditions on demand, the instantaneous benefit from a deviation is higher in the case of market sharing agreements, where the firm still produces the monopoly quantity on one market, and responds optimally to the monopoly quantity on the other market, than under production quotas, where the firms responds optimally to half the monopoly quantity on both markets. Furthermore, the payoff received by the firms after a deviation (both in the Nash reversion and optimal punishment cases) are identical. Hence, firms have a stronger incentive to deviate in the case of market sharing agreements.

When the value of the fixed cost increases, the incentives to deviate from market sharing agreements are lower, as firms become more reluctant to enter the other market. This is illustrated by the fact that (both in the Nash reversion and optimal punishment cases), *the threshold value of the discount factor is decreasing in the fixed cost in the case of market sharing agreements*. On the other hand, this effect is absent in the case of production

[5]We interpret this fixed cost as a marketing cost. In order to sell on the market, the firm needs to advertise its product, establish retailing channels, etc. If the firm sells on two separate markets, this fixed cost is necessarily duplicated.

quotas (where firms always incur the fixed cost on both markets), and we show that (both in the Nash reversion and optimal punishment cases), *the threshold value of the discount factor is either independent or increasing in the fixed cost in the case of production quotas*. Put together, the previous two statements show that, as the fixed cost increases, collusion becomes easier to sustain in market sharing agreements and (weakly) harder to sustain in the case of production quotas. We conclude that there exists a threshold value of the fixed cost such that *collusion is easier to sustain through production quotas if the fixed cost is below the threshold and through market sharing agreements if the fixed cost is above the threshold.*

To the best of our knowledge, this paper is the first to compare explicitly collusion under production quotas and market sharing agreements. However, our analysis bears a close connection to the study of multimarket contact by Bernheim and Whinston (1990). In a model where firms set prices, Bernheim and Whinston (1990) first argue that with identical firms and markets, the existence of several markets does not facilitate collusion – a result which does not hold in our model where firms set quantities, and the presence of several markets affects the incentives to collude.[6] In one of the models they analyze, they assume that two firms have different marginal costs of production on two markets, and show that the development of "spheres of influence", whereby each firm specializes on the market where it is most efficient, is the most effective way to sustain collusion. Our results complement Bernheim and Whinston (1990)'s analysis, as we prove that market sharing agreements may indeed be the easiest way to sustain collusion, but in a different model where firms are identical and incur a fixed cost on every market. In another related paper, Gross and Holahan (2003) have recently studied the sustainability of market sharing agreements in a model where each firm possesses a home market, and incurs a transportation cost to serve the foreign market. In a Bertrand model with linear demand, when firms employ Nash reversion strategies, they show that the minimal threshold value under which monopoly profit can be sustained is

[6] In an early version of the paper, Bernheim and Whinston (1986) do discuss the effect of multimarket contact in a Cournot oligopoly.

nonmonotonic in the transportation cost. This result stems from the fact that the value of the game following a deviation (the one-shot profit from the deviation and the discounted value of the Nash equilibrium following the deviation) is nonmonotonic in the transportation cost. As our analysis focusses on symmetric firms and symmetric markets, these results are not directly comparable to ours.

In this paper, we restrict attention to collusion among two firms. If the industry consists of a larger number of firms, collusion may be hindered by the fact that firms would rather free-ride on the formation of a cartel by the other firms than participate in the collusive agreement (Stigler, 1950). In a companion paper (Belleflamme and Bloch, 2004), we have studied this problem in the case of market-sharing agreements, and analyzed the incentives to participate in a "collusive network", where firms are linked by reciprocal agreements. This analysis shows that, as opposed to cartels which must group a large fraction of the firms in the industry (see, for example, Salant, Switzer and Reynolds, 1983), collusive networks can contain small components. In Belleflamme and Bloch (2004), we have assumed that collusive agreements were enforceable ; the present paper complements the analysis by studying precisely conditions under which these agreements are sustainable.

The rest of the paper is organized as follows. We briefly introduce the model (taken from Abreu, 1986) in the next section. We then discuss in turn the Nash reversion strategies, and globally optimal punishment strategies. The last section contains our conclusions and directions for future research.

2 The Model

We consider the same duopoly model as Abreu (1986). Two identical firms produce a homogeneous good at constant marginal cost $c > 0$. They can sell on two separate, identical markets, with inverse demand $P(Q)$ where $P(.)$ is continuous, nonincreasing, $P(0) > c$ and $\lim_{Q\to\infty} P(Q) = 0$. Firms compete by setting quantities. Each firm incurs a fixed cost F per market, representing advertising and marketing expenses.

As in Abreu (1986), we assume that there is a unique monopoly quantity on each market defined by:

$$q^m = \arg\max_q q(P(q) - c),$$

and that $q(P(q)-c)$ is monotonically increasing until q^m and monotonically decreasing after q^m. Monopoly profits are denoted Π^m.

We also suppose that the one shot duopoly game has a unique symmetric pure strategy equilibrium, with quantities $q^c \neq q^m/2$ and profit Π^c.

As in Abreu (1986), the following two functions will play a crucial role in the analysis. For any q, let $\pi(q)$ denote the profit obtained by a firm which responds optimally to the quantity q. Formally,

$$\pi(q) = \max_z z(P(q+z) - c).$$

We also define $G(q)$ as the profit obtained by a firm when both firms produce the same quantity q,

$$G(q) = q(P(2q) - c).$$

Notice that, at the symmetric Cournot equilibrium, $G(q^c) = \pi(q^c)$, and that by assumption $G(.)$ is monotonically increasing until $q^m/2$ and monotonically decreasing after $q^m/2$. We finally assume that $F < \pi(q^m)$, so that a firm has an incentive to enter the market of another firm when it produces the monopoly quantity. As $q^m > q^c$, this implies that $F < \Pi^c$ so that both firms serve both markets in the noncooperative outcome.

Abreu (1986) establishes the following useful properties on the functions G and π:[7]

Lemma 1 (Abreu, 1986) *The following properties hold.*

(i) If $q_1 > q_2 \geq 0$, *either* $\pi(q_1) < \pi(q_2)$ *or* $\pi(q_1) = \pi(q_2) = 0$.

(ii) $q^c > q^m/2 > 0$ *and* $G(q^m/2) > G(q^c) > 0$.

(iii) The function π *is convex.*

The two firms are engaged in a repeated interaction, and the duopoly game is played for an infinite number of periods, $t = 1, 2, ...$ We consider two types of strategies in the repeated game: the "grim strategies" where firms

[7] These properties appear as Lemma 2 p. 198, Lemma 4 p. 200 and Lemma 21 p. 207 in Abreu (1986).

revert to the noncooperative Nash equilibrium after a deviation (Friedman, 1971) and the strategies based on optimal punishment schemes introduced by Abreu (1986).

3 Nash Reversion

In this section, we analyze the strategies where firms revert to the noncooperative equilibrium. Formally, we define the Nash reversion strategies as follows.

Definition 2 *Nash Reversion Strategies*

- Start the game by abiding by the cooperative agreement.
- Cooperate as long as the cooperative agreement has been observed in all preceding periods.
- If one of the players deviates from the cooperative agreement at period t, play q^c from period $t+1$ on.

In the case of market sharing agreements, the Nash reversion strategies form a subgame perfect equilibrium if and only if:

$$\frac{1}{1-\delta}(\Pi^m - F) \geq \Pi^m - F + \pi(q^m) - F + \frac{\delta}{1-\delta}(2\Pi^c - 2F)$$

or

$$\delta \geq \tilde{\delta}_{ms} = \frac{\pi(q^m) - F}{\Pi^m + \pi(q^m) - 2\Pi^c}.$$

In the case of production quotas, these strategies form a subgame perfect equilibrium if and only if:

$$\frac{1}{1-\delta}(\Pi^m - 2F) \geq 2\pi(q^m/2) - 2F + \frac{\delta}{1-\delta}(2\Pi^c - 2F)$$

or

$$\delta \geq \tilde{\delta}_{pq} = \frac{2\pi(q^m/2) - \Pi^m}{2\pi(q^m/2) - 2\Pi^c}.$$

Notice that the threshold values $\tilde{\delta}_{ms}$ and $\tilde{\delta}_{pq}$ both belong to the interval $(0, 1)$ because $2\pi(q^m/2) > \Pi^m > 2\Pi^c$. In a market sharing agreement, the firm only incurs the fixed cost on the other market following a deviation.

Hence, an increase in the fixed cost makes the deviation from the cooperative agreement less attractive, and collusion is easier to sustain when the fixed cost increases. By contrast, in the case of production quotas, firms incur the fixed costs on both markets during the entire play of the game, and hence, the threshold value is independent of the fixed cost.

We now compare collusion under market sharing agreements and production quotas. A simple computation shows that $\tilde{\delta}_{pq} \geq \tilde{\delta}_{ms}$ if and only if:

$$F \geq \widehat{F} = \frac{(\pi(q^m) + \Pi^m - 2\pi(q^m/2))(\Pi^m - 2\Pi^c)}{2\pi(q^m/2) - 2\Pi^c}$$

Because the function π is convex (see (iii) of Lemma 1),

$$\pi(q^m) + \Pi^m - 2\pi(q^m/2) = \pi(q^m) + \pi(0) - 2\pi(q^m/2) \geq 0.$$

Hence, $\widehat{F} > 0$ and when the fixed cost is zero, $\tilde{\delta}_{pq} < \tilde{\delta}_{ms}$ so that collusion is easier to sustain under production quotas. This result is easily interpreted. In the absence of fixed cost, the only difference between market sharing agreements and production quotas stems from the profit from the deviation. When the firms produce $q^m/2$ on both markets, this profit is smaller than when one firm retains its monopoly profit on its own market, and enters the other firm's market. Hence, collusion is easier to sustain when firms are present on both markets.

On the other hand, when the fixed cost becomes large, the threshold value of collusion under market sharing agreement becomes small, and collusion becomes easier to sustain under market sharing agreements. We summarize this finding in the next Proposition.

Proposition 3 *Suppose that firms employ Nash reversion strategies. Then collusion is easier to sustain under production quotas if $F \leq \widehat{F}$ and easier to sustain under market sharing agreements if $F \geq \widehat{F}$.*

Proposition 3 establishes the existence of a threshold value of the fixed cost such that collusion is easier to sustain through production quotas below the threshold and easier to sustain with market sharing agreements above the threshold. However, this comparison is biased because the cooperative profit obtained when firms are present on both markets is always smaller than the profit obtained under market sharing agreements. For high values of the fixed cost, the optimal strategy of the firm is always to serve separate markets – a strategy which makes collusion easier and profits higher. For lower values of the fixed costs, if market sharing agreements cannot be sustained, firms face a trade-off between sustaining the collusive outcome on both markets through production quotas, or sustaining a profit below the monopoly profit on a single market.

4 Optimal Punishment Schemes

When firms compete in quantities, the Nash reversion strategies analyzed in the preceding section are not optimal, and collusion can more easily be sustained using alternative punishment schemes. Abreu (1986) and (1988) characterizes optimal punishment schemes as "stick and carrot" strategies, where, following a deviation, firms produce a high quantity (resulting in very low profits) for one period, and then return to the cooperative outcome. Intuitively, these punishment schemes are optimal, because setting a very high quantity after the deviation minimizes the incentive to deviate from the punishment scheme, for a fixed value of the game following the deviation.

Definition 4 *Stick and Carrot Strategies*

- Start the game by abiding by the cooperative agreement.
- Cooperate as long as the cooperative agreement has been observed in all preceding periods.
- (Punishment phase) If one of the players deviates from the cooperative agreement at period t, play $\overline{q}$ at period $t+1$ and return to the cooperative agreement at period $t+2$.
- If one of the players chooses a quantity $q \neq \overline{q}$ during the punishment phase, start the punishment phase again at the following period.

Abreu (1986) notes that this stick and carrot strategy is *globally optimal* if the firms obtain a value of zero following the deviation. Hence, in a globally optimal punishment scheme, the quantity $\overline{q}$ is chosen so that the initial losses suffered by the firms in the punishment phase are exactly recouped by the cooperative profits made in the following periods. In the case of market sharing agreements, we can thus characterize $\bar{q}_{ms}$ by the following equation:

$$\bar{q}_{ms} = \max\{q|2G(q) - 2F + \frac{\delta}{1-\delta}(\Pi^m - F) \geq 0\}.$$

Similarly, in the case of production quotas, we define the quantity $\bar{q}_{pq}$ by

$$\bar{q}_{pq} = \max\{q|2G(q) - 2F + \frac{\delta}{1-\delta}(\Pi^m - 2F) \geq 0\}.$$

As $G(q^c) - F > 0$, the function $G(.)$ is strictly decreasing for $q > q^m/2$ and $\lim_{q\to\infty} G(q) = -\infty$, the equations above define unique values $\bar{q}_{ms}$ and $\bar{q}_{pq}$, which satisfy $\bar{q}_{ms} > q^c$ and $\bar{q}_{pq} > q^c$. Furthermore, implicit differentiation shows that $\bar{q}_{ms}$ and $\bar{q}_{pq}$ are decreasing in F and increasing in δ. Finally, we note that $\bar{q}_{pq} \leq \bar{q}_{ms}$ as the profit of the cooperative agreement is larger in the case of market sharing agreements than production quotas.

The globally optimal punishment schemes where firms produce $\bar{q}_{ms}$ and $\bar{q}_{pq}$ can only be sustained if no firm has an incentive to produce a quantity $q \neq \bar{q}_{ms}$ (respectively $q \neq \bar{q}_{pq}$) during the first period of the punishment phase. In our context, firms can deviate by either abstaining from producing on both markets or by setting their optimal response on both markets. In the first case, they obtain a zero profit for that period. In the second case, they obtain a profit $2\pi(\bar{q}_{ms}) - 2F$, (respectively $2\pi(\bar{q}_{pq}) - 2F$) during that period.[8] Notice that, if $\pi(\bar{q}_{ms}) - F < 0$ (respectively $\pi(\bar{q}_{pq}) - F < 0$), the firm's optimal deviation is to abstain from producing, and firms will never deviate from the punishment scheme, since a deviation will induce a value of zero, which is equal to the value obtained at the punishment phase. If however $\pi(\bar{q}_{ms}) - F > 0$ (respectively $\pi(\bar{q}_{pq}) - F > 0$), the punishment scheme cannot be sustained.

We thus focus attention on those parameter configurations for which the punishment scheme can be sustained, i.e., $\pi(\bar{q}_{ms}) - F \leq 0$ or $\pi(\bar{q}_{pq}) - F \leq 0$. Because $\bar{q}_{ms}$ and $\bar{q}_{pq}$ are increasing in δ and $\pi(.)$ is a decreasing function,

[8] Selling on one market only is a weakly dominated strategy. If $\pi(\overline{q}) - F > 0$, the firms prefer to sell on both markets. If $\pi(\overline{q}) - F < 0$, they prefer to abstain. If $\pi(\overline{q}) - F = 0$, they are indifferent between selling on one or two markets or abstaining from producing.

there exists lower bounds $\underline{\delta}_{ms}(F)$ and $\underline{\delta}_{pq}(F)$ such that the globally optimal punishment scheme can be sustained for $\delta \geq \underline{\delta}_{ms}(F)$ in the case of market sharing agreements, and for $\delta \geq \underline{\delta}_{pq}(F)$ in the case of production quotas.[9] Furthermore, as $\bar{q}_{pq} \leq \bar{q}_{ms}$ for all values of δ, the equalities $\pi(\bar{q}_{ms}) - F = \pi(\bar{q}_{pq}) - F = 0$ can only be satisfied if $\delta_{pq}(F) \geq \underline{\delta}_{ms}(F)$. Hence, the region of parameters for which the optimal punishment scheme can be sustained for market sharing agreements always contains the region of parameters for which the optimal punishment scheme can be sustained for production quotas. We illustrate these remarks by considering markets with linear demand.

Example 5 *Let $P(Q) = \alpha - Q$ for $Q \leq \alpha$ and $P(Q) = 0$ for $Q > \alpha$.*

In this case, we have $\Pi^m = (\alpha - c)^2/4$ and $G(q) = q(\alpha - c - 2q)$. Easy computations show that

$$\begin{aligned}\bar{q}_{ms} &= \frac{(1-\delta)(\alpha - c) + \sqrt{(1-\delta)\left((\alpha-c)^2 - 8F + 4\delta F\right)}}{4(1-\delta)}, \\ \bar{q}_{pq} &= \frac{(1-\delta)(\alpha - c) + \sqrt{(1-\delta)\left((\alpha-c)^2 - 8F\right)}}{4(1-\delta)} < \bar{q}_{ms}.\end{aligned}$$

A sufficient condition for $P(2\bar{q}_{ms})$ and $P(2\bar{q}_{pq})$ to be non-negative is

$$\delta \leq \bar{\delta} = \frac{4\alpha c}{(\alpha + c)^2},$$

where $\bar{\delta}$ can be made arbitrarily close to one by increasing α while keeping $(\alpha - c)$ constant. Hence, in what follows, we suppose that $P(2\bar{q}_{ms})$ and $P(2\bar{q}_{pq})$ are both positive. The conditions $\pi(\bar{q}_{ms}) - F \leq 0$ and $\pi(\bar{q}_{pq}) - F \leq 0$ give rise to the following threshold values:

$$\begin{aligned}\underline{\delta}_{ms}(F) &= \frac{8(\alpha-c)^2 - 48(\alpha-c)\sqrt{F} + 72F}{\left(3(\alpha-c) - 8\sqrt{F}\right)^2 + 4F}, \\ \underline{\delta}_{pq}(F) &= \frac{8(\alpha-c)^2 - 48(\alpha-c)\sqrt{F} + 72F}{\left(3(\alpha-c) - 8\sqrt{F}\right)^2}.\end{aligned}$$

Figure 1 draws the two functions $\underline{\delta}_{ms}(F)$ (solid curve) and $\underline{\delta}_{pq}(F)$ (dotted curve) in the case where $\alpha - c = 1$.

[9] This remark parallels Abreu (1986)'s result that there exists a lower bound $\underline{\delta}$ such that globally optimal punishment schemes can be sustained for $\delta \geq \underline{\delta}$. (Abreu (1986), Theorem 18, p. 205).

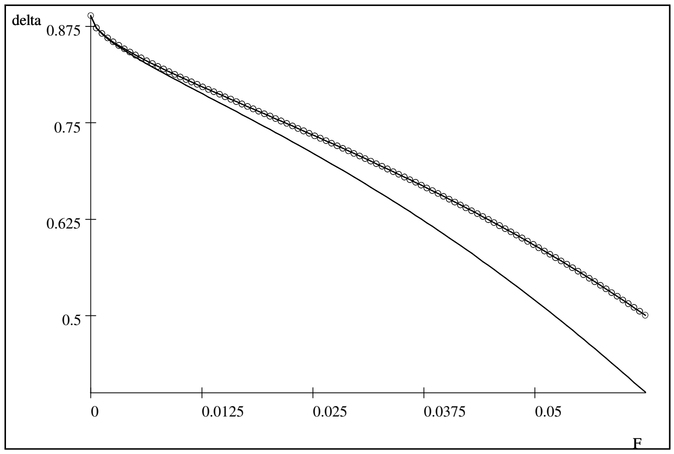

Figure 1. Sustainability of optimal punishments schemes

We now turn to the firms' incentives to deviate from the cooperation phase, assuming that the globally optimal punishment scheme can be sustained. In the case of market sharing agreements, a firm abides by the cooperative agreement if:

$$\frac{1}{1-\delta}(\Pi^m - F) \geq \Pi^m - F + \pi(q^m) - F$$

or

$$\delta \geq \delta_{ms}(F) = \frac{\pi(q^m) - F}{\Pi^m - F + \pi(q^m) - F}.$$

The relation between the fixed cost and the threshold value of the discount factor is less transparent than in the case of Nash reversion. An increase in the fixed cost simultaneously decreases the permanent value of cooperation and the one-shot profit from the deviation. Firms only incur the fixed cost of entering the other market when they deviate, and hence, an increase in the fixed cost results in a higher decrease in the one-shot profit from the deviation than in the one-shot cooperative profit. A simple computation shows that this is the dominant effect, and that an increase in the fixed cost results in a greater decrease in the one-shot profit from the deviation than in the permanent value of cooperation. Formally, as $\Pi^m > \pi(q^m)$, it is easy to check that δ_{ms} is a decreasing function of the fixed cost.

In the case of production quotas, a firm abides by the cooperative agreement if:

$$\frac{1}{1-\delta}(\Pi^m - 2F) \geq 2\pi(q^m/2) - 2F$$

or

$$\delta \geq \delta_{pq}(F) = \frac{2\pi(q^m/2) - \Pi^m}{2\pi(q^m/2) - 2F}.$$

In the case of production quotas, an increase in the fixed cost simultaneously affects the permanent value of cooperation and the one-shot profit from the deviation in the exact same way. The decrease in the permanent value of cooperation exceeds the decrease in the one-shot profit from the deviation. Hence, an increase in the fixed cost makes cooperation less likely, and one can easily check that δ_{pq} is an increasing function of the fixed cost.

For $F = 0$,

$$\delta_{pq}(0) = \frac{2\pi(q^m/2) - \Pi^m}{2\pi(q^m/2)}, \delta_{ms}(0) = \frac{\pi(q^m)}{\Pi^m + \pi(q^m)}$$

and

$$\delta_{ms}(0) - \delta_{pq}(0) = \frac{\Pi^m(\Pi^m + \pi(q^m) - 2\pi(q^m/2))}{2\pi(q^m/2)(\Pi^m + \pi(q^m))} > 0$$

by convexity of the function $\pi(.)$.

If $F = \Pi^m/2, \delta_{pq} = 1 > \delta_{ms}$. As δ_{ms} is decreasing in F and δ_{pq} is increasing in F, there exists a unique value $\widetilde{F}$ such that $\delta_{pq}(F) \leq \delta_{ms}(F)$ for all $F \leq \widetilde{F}$ and $\delta_{pq}(F) \geq \delta_{ms}(F)$ for all $F \geq \widetilde{F}$.

When firms employ globally optimal punishment, the threshold values for which cooperation can be sustained thus follow the same pattern as in the case of Nash reversion strategies. Collusion is easier to sustain under production quotas for low values of the fixed cost, and easier to sustain with market sharing agreements for high values of the fixed cost. However, the analysis is incomplete because globally optimal punishment strategies only form a subgame perfect equilibrium of the repeated game if the punishment strategies are sustainable, i.e. $\delta \geq \underline{\delta}_{ms}(F)$ (respectively $\delta \geq \underline{\delta}_{pq}(F)$). Hence, collusion is sustainable with globally optimal punishment schemes if and only if $\delta \geq \max\{\delta_{ms}(F), \underline{\delta}_{ms}(F)\}$ in the case of market sharing agreements, and $\delta \geq \max\{\delta_{pq}(F), \underline{\delta}_{pq}(F)\}$ in the case of production quotas.

Now, if $\underline{\delta}_{ms}(F) \geq \delta_{ms}(F)$, then $\max\{\delta_{pq}(F), \underline{\delta}_{pq}(F)\} \geq \underline{\delta}_{pq}(F) \geq \underline{\delta}_{ms}(F)$ $= \max\{\delta_{ms}(F), \underline{\delta}_{ms}(F)\}$, and collusion is always easier to sustain under market sharing agreements. If on the other hand, $\delta_{ms}(F) \geq \underline{\delta}_{ms}(F)$, then for $F \geq \widetilde{F}$, $\max\{\delta_{pq}(F), \underline{\delta}_{pq}(F)\} \geq \delta_{pq}(F) \geq \delta_{ms}(F) = \max\{\delta_{ms}(F), \underline{\delta}_{ms}(F)\}$, and collusion is again easier to sustain under market sharing agreements. We have thus established the following Proposition.

Proposition 6 *Suppose that the firms adopt globally optimal stick and carrot strategies. Then there exists a value of the fixed cost* $\widetilde{F}$ *such that collusion is always easier to sustain under market sharing agreements if* $F \geq \widetilde{F}$.

The preceding proposition shows that market sharing agreements are always easier to sustain for high values of the fixed cost, and, as opposed to the case of Nash reversion, may also be easier to sustain for low values of the fixed cost, because they induce a more severe punishment after a deviation. We illustrate this fact by returning to the example with linear demand, where indeed market sharing agreements are always easier to sustain than production quotas.

Example 7 *(continued)*

We easily compute $\pi(q^m) = \frac{(\alpha-c)^2}{16}$ and $\pi(q^m/2) = \frac{9(\alpha-c)^2}{64}$. Hence

$$\begin{aligned} \delta_{ms}(F) &= \frac{(\alpha-c)^2 - 16F}{5(\alpha-c)^2 - 32F}, \\ \delta_{pq}(F) &= \frac{(\alpha-c)^2}{9(\alpha-c)^2 - 64F}. \end{aligned}$$

For $\alpha - c = 1$, Figure 2 puts together the functions defining the sustainability of optimal punishment schemes ($\underline{\delta}_{pq}(F)$ and $\underline{\delta}_{ms}(F)$ as, respectively, thin solid and dotted curves) and the sustainability of cooperation ($\delta_{pq}(F)$ and $\delta_{ms}(F)$ as, respectively, thick solid and dotted curves). It shows that the binding constraint is always the sustainability of the optimal punishment scheme, $\underline{\delta}_{ms}(F) \geq \delta_{ms}(F)$ for all F, so that market sharing agreements are easier to sustain for all values of the fixed cost.

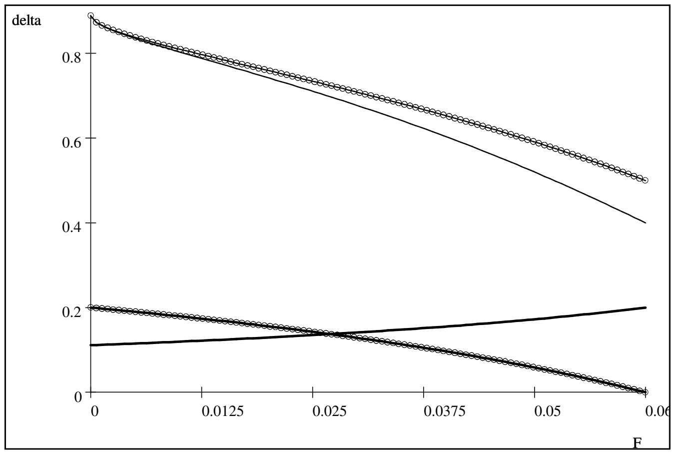

Figure 2. Sustainability of optimal punishments and cooperation

5 Conclusion

This paper compares production quotas and market sharing agreements in a simple Cournot duopoly with two identical firms and two identical markets, and emphasizes the role of fixed costs in the determination of the optimal collusion regime. In industries with low entry barriers, firms have an incentive to be present on all the markets in order to sustain collusion. By contrast, we expect to observe market sharing agreements in industries with high costs of accessing each market.

The importance of fixed costs in the choice between production quotas and market sharing agreements concurs with a very basic intuition. If the costs of accessing markets are high, firms will of course prefer to share markets. However, we note that, in the absence of collusion, in the unique equilibrium outcome, firms will be active on both markets. Market sharing agreements thus emerge as a natural form of collusion in industries with high fixed costs but where entry barriers are not high enough to discourage entry.

We are of aware of several limitations of our analysis, which should be considered in future research. First, we have focussed attention on conditions under which the monopoly profit can be sustained on the market. Alternatively, as Bernheim and Whinston (1990), we could have considered, for a fixed value of the discount factor, the best collusive profit that firms can achieve. We conjecture that the results of our model would still hold under this alternative formulation. For low values of the fixed cost, we expect that the optimal collusive profit of production quotas would exceed the collusive profit of market sharing agreements, and that the conclusion would be reversed for high values of the fixed cost. Second, by considering identical firms and markets, we do not allow firms to have a privileged access to a "home" market. Hence, our model cannot capture the natural situations analyzed by Gross and Holahan (2003) where firms are active on geographically separated markets and incur a transportation cost to serve foreign markets. Introducing asymmetries among firms and markets would greatly complicate the analysis in the case of optimal punishment schemes, because firms would have to employ asymmetric strategies during the punishment phase. We believe that this is an important open question for future research.

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